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Assessment of the Ocean Quahog (*Arctica islandica*) Stock in Southwest New Brunswick

Évaluation des stocks de quahog nordique (*Arctica islandica*) du sud-ouest du Nouveau-Brunswick

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ABSTRACT

Surveys of the Ocean Quahog (*Arctica islandica*) populations in southwest New Brunswick were conducted for the Mace's Bay area in 2006, and the Grand Manan area in 2007. These surveys estimated the biomass as 42,729 t, with Mace's Bay area accounting for 91% of this biomass. Natural mortality was estimated to be 0.12, which is higher than other Scotian Shelf populations. This higher mortality rate is supported by the length frequencies from the surveys and limited ageing data. Using the recommended target Fishing Mortality (F) of 0.33M, the harvest levels would be 1,537 t for Mace's Bay and 155 t for Grand Manan.

RÉSUMÉ

Des relevés de la population de quahogs nordiques (*Arctica islandica*) dans le sud-ouest du Nouveau-Brunswick ont été effectués dans la région de la baie de Mace en 2006 et dans celle de Grand Manan en 2007. Les estimations issues de ces relevés indiquent une biomasse de 42 729 tonnes, dont 91 % se trouve dans la baie de Mace. La mortalité naturelle qui est estimée à 0,12 est plus élevée que celle des autres populations du plateau néo-écossais. Ce taux de mortalité plus élevé est appuyé par les fréquences de longueur découlant des relevés et des données limitées sur le vieillissement. En appliquant le taux cible de mortalité par pêche recommandé (F) de 0,33 MB, le niveau acceptable d'exploitation du quahog nordique serait de 1 537 tonnes dans la baie de Mace et de 155 tonnes pour les eaux de Grand Manan.

1.0 – INTRODUCTION

1.1 – HISTORICAL FISHERY

The presence of Ocean Quahogs (*Arctica islandica)* in south western New Brunswick was noted as far back as the 1800's (Stimpson 1854; Ganong 1885, 1887, 1889). It does not show up in records of landings during the 1800's, but Ganong (1889) notes it as, "A useful and good food-mollusc, and frequently eaten along with *Venus mercenaria*, from which it is not easily distinguished except by large dealers. It is said by good judges to be of excellent flavour." He also states, "They are neither abundant enough nor easily enough obtained to make it pay to take them to market. We cannot find that they are ever sold by themselves in our towns." From this it is concluded that Ocean Quahogs were known and consumed as far back as the 1800's, but there was limited harvesting and they entered the market with Bay Quahogs (*Mercinaria mercinaria*).

1.2 – CURRENT STATUS

In 1997, seven stage one licences for Ocean Quahogs were issued in Lobster Fishing Area (LFA) 38 and one in LFA 36. A conservation harvesting plan was approved by the Southwest New Brunswick (SWNB) Developing Species Advisory Board and Department of Fisheries and Oceans (DFO) Regional Resource Management. In 1998, the Developing Species Advisory Board requested and received permission from Regional Resource Management and approval from DFO Science to treat the two LFAs as separate fisheries with six licences in each. Experimental fishing occurred during 1997-2002, but marketing problems and costs of Canadian Food Inspection Agency (CFIA) inspections (often exceeding the value of the product) hindered development of the fishery.

In 2002, a regional review of exploratory licences identified the inshore SWNB quahog fishery as one that had been in place for a number of years with no progress, and the licences were not reissued in 2003. In 2004, the DFO area offices, Science and Regional Resource Management were asked to:

1) Thoroughly review the number of experimental or exploratory licences an area can realistically support to provide Science survey data.

2) Determine the participation requirements to ensure they reflect actual active fishing as a prerequisite participation requirement within a Joint Project Agreement (JPA).

The Regional Director General also requested that a departmental Habitat Review be undertaken for all existing inshore experimental/exploratory quahog licences, and new proposals, prior to allowing consideration for approval.

A JPA to conduct survey work in SWNB for a biomass estimate was signed in 2006 between DFO and the Southwest New Brunswick Quahog Group Inc. The results from this survey work form the basis for this assessment.

Fishing took place from January to March 2007 with 12 t landed, but then clam fishing throughout the Bay of Fundy was closed due to Paralytic Shellfish Poison (PSP) contamination. Interest in the fishery was renewed in 2009, but no fishing took place.

2.0 – METHODS

2.1 – SURVEY DESIGN

Two sources of data were used to define initial areas of interest for a survey: Ocean Quahog fishing activity up to 2003 for SWNB from commercial log data, and records that contained comments on by-catches of Ocean Quahogs from the Scallop Production Area (SPA) 6 scallop surveys (Figure 1). Areas of interest were plotted and polygons defining the survey areas assigned to them. A meeting with quahog fishermen refined these areas and identified additional areas of interest. A survey design, survey protocols and cost estimate were produced and accepted, and a JPA to conduct the survey was signed.

Two-hundred and eight-five survey stations were divided between the polygons, proportional to their area. The stations were randomly assigned, with the provision that the stations would be at least 0.5 km apart. The station assignment was plotted to confirm that the areas would be covered by the station assignment (Figure 2).

During the survey, the area was expanded if there were good catches of quahogs on the edge of the survey area or if the fishers thought the area should be expanded once they were on location.

2.2 – SURVEY GEAR

The Mace's Bay portion of the survey was conducted in February 2006 using the vessel *Miss October*, a 44.19 foot length overall (LOA), 15 gross tonne Cape Island style fishing vessel equipped with a dry dredge. The *Miss October* used a dredge 1.63 m wide by 2.26 m long and 48 cm high. The blade was 1.19 m wide and set to 5 cm below the runners, which were 20 cm wide. The cage was made of 1.27 cm bar with 1.9 cm spacing and no liner.

The Grand Manan portion of the survey was conducted in February 2007 with the vessel *Beverly Ann II*, a 44.38 foot LOA, 15 gross tonne Cape Island style vessel, also equipped with a dry dredge. The dredge used by the *Beverly Ann II* was 1.49 m wide, 2.41m long and 0.69 m high. The blade width was 0.91 m and the depth as set to 12 cm below the runners, which were 24 cm wide. The construction was 1.6 cm bar with 1.9 cm spacing, and it was lined with 2.54 cm square mesh wire.

2.3 – TOW PROCEDURES

For the Mace's Bay stations, a three minute tow was done at each station, and then the dredge was hauled up. The dredge was then lowered into the propeller wash from the vessel and held there for 5 to 15 minutes to wash the mud out of the dredge. The same procedure was followed for the Grand Manan stations, with the exception that tow time was five minutes following the fishing practice in the areas. The longer tow time was supported by the presence of less mud in the dredge. Tow distance was calculated with the ships navigation program.

2.4 – CATCH PROCESSING

The contents remaining in the dredge were dumped on a washing table consisting of spaced bars, and a hose was used to liquefy remaining mud and rinse quahogs. The mud from the wash table was collected in a plastic tote box and any organisms remaining in it or on the wash table were recorded for by-catch. The catch of quahogs was weighed, and a subsample of up to 100 quahogs was measured for length frequencies. A length stratified sample of three quahogs per 5 mm shell length interval was retained and frozen for later morphometric processing in a DFO laboratory.

In the laboratory, the morphometrics samples were thawed, and the length, width and height of each quahog was measured to the nearest mm. The weights, recorded to the nearest 0.01 g, were total wet weight (whole animal), total wet tissue weight (shell removed), wet foot weight, gutted foot weight (gonad and digestive gland removed), remaining tissue weight, and shell weight. For all except total wet weight and total wet tissue, the dry weight was recorded after drying the sample at 90°C to constant dry weight.

2.5 – AGEING

The age of a subsample of the quahogs processed for morphometrics was estimated using the acetate peel technique (Thompson et al. 1980a, 1980b; Ropes et al. 1984a, 1984b). The left valve was sectioned using a low-speed diamond saw, embedded in epoxy-resin, polished with silica carbide grinding powder of successively finer grit (240, 400, and 600), polished with a polishing compound, and etched with 1% hydrochloric acid for one minute. Acetate peels were completed by applying an acetate sheet (0.013 mm thick) over the etched surface, after flooding it with acetone. After a one-hour drying period, the acetate was peeled off and sandwiched between glass slides for examination under a compound microscope. The internal growth bands were counted both in the hinge tooth and along the entire section. Although the number of bands was consistent in both the section margin and hinge area, the count from the section margin was used as growth bands were wider and, thus, provided higher resolution. This method has been validated for Ocean Quahogs using the bomb radiocarbon method (Kilada et al. 2007).

Ageing results were validated by using multiple agers. Precision estimates were calculated by using the coefficient of variation (CV) as described by Chang (1982) and Morales-Nin and Panfili (2002). Coefficient of variation is more flexible and statistically more robust than other measures of precision, such as percent agreement or Average Percent Error (Kimura and Lyons 1991). Results from cross ageing had to achieve a CV less than 5% before the agers were considered in agreement.

A von Bertalanffy growth curve was fit to the age data by non-linear regression using the statistical package SPLUS:

$$L_t=L_\infty(1-e^{-k(t-t_o)}) \qquad 1$$

where L_t is the length at age t; L_∞ is the asymptotic length; k is a growth coefficient; and t_o is the theoretical age at zero length.

2.6 – SIZE AND AGE AT SEXUAL MATURITY

For the Mace’s Bay area, a sample of smaller quahogs was collected to examine the size and age of maturity. Each animal was measured to the nearest mm and stored in 10% formalin in seawater. The preserved samples were transported to the laboratory, where the foot portion, which contains the gonad material, was separated for histological processing. Histology and staging was done by the Aquatic Diagnostic Services of the Atlantic Veterinary Collage at the University of Prince Edward Island (UPEI). Gonad sections were classified into the same six maturity stages used for visual interpretation (Ropes 1968; Rowell et al. 1990): 1) early active; 2) late active; 3) ripe; 4) spawning; 5) spent; and 6) immature. The proportion of mature individuals was plotted against size. A logistic curve was fit to the data using maximum likelihood:

$$P = e^{a + bL} / (1+e^{a + bL}) \qquad 2$$

where P is the proportion of mature individuals in the sample, L is the shell length (mm), a and b are constants. The quahog length corresponding to 50% mature was calculated as: $L_{50} = -a/b$.

For the age of maturity sample, ageing was done by two readers using thin sections of the chondrophore. The lines in older sections were enhanced by staining with Mutvei's solution (Mutevi et al 1994; Schöne et al 2005; Soldati et al 2009). The readers first read each section separately and then sections with a discrepancy between readers were read by both readers together to come up with a consensus age.

A logistic curve was fit to the age at maturity data using the same method used for the size at maturity data.

2.7 – BIOMASS ESTIMATION

The biomass in the survey area was calculated by three methods:

1 Random sampling statistics:

$$B = As/At * \overline{C} \qquad 3$$

Where B = Biomass, As = survey area, At = Area of standard tow and $\overline{C}$ is mean catch per standard tow.

2 Areal expansion using inverse distance weighting with the ACON Data Visualization software package (Black 1991).

3 Spatial analysis using kriging after modeling the spatial relationship with a variogram using the Surfer software package (Golden Software Inc. 2009). This was only done for the Mace's Bay survey.

Since commercial gear was used for survey the survey biomass estimate corresponds to fishable biomass.

The kriging estimate includes spatial correlation that was calculated using the Surfer software package. For this analysis, the spatial correlation was first modeled with a variogram using a spherical model with a nugget. The variogram model was fit to the data with least squares, and then used to produce a kriged grid. The biomass was then calculated from this grid. For both these analysis, the stations too rocky to dredge were assigned a catch of 0.0 kg. The variogram was cross-validated using the formulas outlined by Cressie (1993):

Cressie's (2.6.15) $$(1/n)\sum_{j=1}^{n}\left\{\left(Z(s_j)-\hat{Z}_{-j}(s_j)\right)/\sigma_{-j}(s_j)\right\} \qquad 4$$

Cressie's (2.6.16) $$\left[(1/n)\sum_{j=1}^{n}\left\{\left(Z(s_j)-\hat{Z}_{-j}(s_j)\right)/\sigma_{-j}(s_j)\right\}^2\right]^{1/2} \qquad 5$$

These formulas cannot prove the variogram is correct; merely that it is not grossly incorrect. If successful, the cross validation means, "one can feel confident that the prediction based on the fitted variogram is approximately unbiased and that the mean-squared prediction error is about right." (Cressie 1993).

2.8 – MORTALITY

Since there has been very little fishing on Ocean Quahogs in SWNB, it was assumed that fishing mortality rate (F) was near zero and the natural mortality rate (M) was equivalent to the total mortality rate (Z). Several methods used for estimating mortality were examined. The first was:

$$Z = 3/T_{MAX} \qquad 6$$

where T_{MAX} is the lifespan of the organism.

The lifespan is usually described as the age at which 5% of the population remains alive. It is an approximation that requires very little data, and is based on the formula:

$$\frac{N_t}{N_o} = e^{-Zt} \qquad 7$$

Taking the time to reduce the year class to 5% of its original numbers the equation becomes:

$$\frac{0.05}{1} = e^{-Zt}$$

$$Log(0.05) = -Zt,$$

$$Z = \frac{2.9957}{t}$$

The second method was Beverton and Holt's (1956) method. This method takes the decline on the right hand side of the length frequency distribution, and uses the von Bertalanffy parameters to apply a time period for the animals to grow through a size range. Total mortality is estimated with the formula:

$$Z = (K(L_\infty - L_m))/(L_m - L') \qquad 8$$

where L' is the smallest length fully represented in the length frequency data, L_m, is the mean length of all clams ≥ L', and K and L_∞ are von Bertalanffy growth curve parameters. This method requires length frequency data and a growth curve, but does not require a large sample to be aged.

The third method is the catch curve method (Chapman and Robson 1960; Ricker 1975), which takes a large aged sample and models the decline in numbers at age:

$$N_t = N_0 * e^{-Zt} \qquad 9$$

where N_0 is the initial number of individuals, t is the period of time (years), and N_t the number alive at time t. Z is estimated with a linear regression of the log transformed numbers at age.

The fourth method examined was the Chapman Robson (C-R) estimate of Z (Chapman and Robson, 1960). This method uses the mean age of animals above the recruitment age to estimate mortality:

$$Z = \ln\left(\frac{1+\bar{a}-1/n}{\bar{a}}\right) \qquad 10$$

where ā is the mean age of quahogs above the recruitment age minus the recruitment age, and n the sample size.

The last three methods require a decision on which sizes/ages to include, as they require the analysis to be based on individuals that are fully recruited to the sampling gear, and, thus, on the descending right limb of the length frequency curve.

For the methods that require age frequencies (catch curve and C-R), the survey age frequency for Maces Bay was estimated from the length frequency data using an age-length key constructed from the aged sample. This was to make sure the length-age key covered the full size range. The age-length key was used to convert the survey length frequencies into age frequencies. The resulting population age frequency was used for the catch curve estimate of Z.

A Maritimes Region DFO Expert Opinion (DFO 2005, reference available on request) on harvest levels for inshore Ocean Quahogs recommended the use of a target F of 0.33M in data poor situations. This was calculated from the biomass estimate using Gulland's Model (Gulland 1971), with modifications (Zhang 1999). The harvest level the fishery is estimated to be able to support is then:

$$H = 0.33\ M\ B_S \qquad 11$$

where M is the natural mortality rate of the population, and B_S is the survey biomass estimate of the target stock.

3.0 – RESULTS

3.1 – SURVEY

The Mace's Bay portion of the survey was completed on schedule in 2006; however, the Grand Manan survey encountered difficulties scheduling a vessel for the survey, and on two occasions the survey was postponed due to conflicts with the lobster fishery. The largest area of interest was not surveyed, as it is an area that is fished by both lobster and crab gear in alternate seasons. As mobile gear has to stay at least 0.5 nautical miles away from any previously set fixed gear, the density of lobster or crab gear prevented the survey vessel from working in the area, and, in retrospect, the industry participants concluded that even if the area was surveyed and showed commercial quantities of Ocean Quahogs, commercial quahog vessels would be unable to fish there.

3.2 – BIOMASS

The survey stations and ACON contouring for Mace's Bay are shown in Figure 3. Standard statistical estimate and kriging were also used for Mace's Bay.

The spatial relationship shown by the variogram (Figure 4) indicates that there is a spatial correlation between stations. A linear relationship was a better fit than the initial spherical relationship. This indicates that stations that are closer together will have catch rates more similar to each other than ones further apart.

To examine this further, the data were converted to UTM coordinates and analysed with the Surfer surface mapping system (Golden Software Inc. 2009). The variogram fit with least squares showed anisotropy, tows were more similar in one direction (105.6 degrees) than others. This analysis produced a nugget value of 929.3 and a slope of 0.8525. The anisotropy ratio, the ratio of the range of the major axis to that of the minor axis, was 1.2. This is considered mild anisotropy, as ratios less than 3 are usually not clearly visible on a map of the data.

The data were gridded using this variogram, and the volume within the survey area calculated. The resulting biomass estimates are shown in Table 1. The ACON and statistical estimates for Mace's Bay are shown in Table 2. The Mace's Bay biomass estimates using the three methods are very similar, with the two spatial methods within 2% of each other.

The biomass estimates for the Grand Manan survey areas are shown in Table 2, and the ACON contouring and station locations can be seen in figures 5 to 11.

For area GM-2, there were large portions of the survey area that were rocky (Figure 5). There were two patches of quahogs identified and two single stations also had quahogs. Two stations in the southern portion were not able to be dredged due to set gear.

The GM-1 area was expanded during the survey, adding a tow deeper outside the original area and two inside close to shore (Figure 6). The inshore stations did yield a few quahogs, but the catches were only 1.25 and 0.1 kg.

In area GM-3, only one station was occupied due to set gear, and the resulting catch was 0.0 kg (Figure 7).

In the GM-8 area, two tows were added close inshore, and these did catch some quahogs (Figure 8). Vessel tows were conducted close in by the cliff as the bottom drops off quickly in this area. The added tows indicate that there were small amounts of quahogs in a very narrow band close to shore towards the southern portion of this area.

The GM-7 area found good catches of quahogs in a narrow band (Figure 9). The contouring overestimates the biomass in this case as it expands the catch rate out to the nearest neighbour. A plot overlaying the catches on multi-beam data available for the area provides some guidance as it shows a rocky ledge on the western side of the survey area (Figure 10). Adding dummy stations with zero catch on the rocky ledge and in deep water helps bring the contoured estimate more in line with the statistical estimate, and limits the areal expansion to a narrower band. There is a possibility that both of these methods still overestimate biomass in this area.

In the GM-6 area, there were gear conflicts with salmon cages and a lack of suitable bottom, mainly gravel and rock. No stations were towed in this area.

The biomass estimates in the Grand Manan areas that were surveyed are shown in Table 2 and all the areas in Figure 11. The biomass is not large, and there are large confidence intervals around them due to the small number of stations in each area. Using the statistical biomass estimates, the biomass for all the Grand Manan areas surveyed amounts to 10% of the biomass of Mace's Bay.

3.3 – AGEING

The ageing results for the Mace's Bay area are shown in Figure 12. The growth curve fit to the data is shown, along with the survey and sample length frequency and the age frequency from the aged sample. Maturity samples were included to increase the number of small quahogs available to fit the growth curve. A population age distribution was not constructed due to the small sample size and large age range. The size distribution in this area is smaller than that found in St. Mary's Bay on the Nova Scotia side of the Bay of Fundy, where most quahogs were between 65 and 85 mm shell height, with the largest at 103 mm; and the majority of the aged sample were over 30 years old, with the oldest 69 (Roddick et al. 2007b). The size and age distribution is much smaller and younger than found offshore on Sable Bank, where the bulk of quahogs caught were over 70 mm and the oldest was 211 years old (Roddick et al. 2007a).

3.4 – MORTALITY

The T_{MAX} method of estimating Z simply depends on the estimate of the lifespan of the organism. For this analysis, it was taken as the size at which the fully recruited numbers are 5% of the total. Table 3 shows the estimate of Z for different values used for the fully recruited size.

The size at recruitment can be approximated by the bar spacing in the dredge and the shell length-width data. Figure 13 shows a log-log regression of shell length on shell width from the morphometrics data. Since quahogs have a hard shell and are relatively immobile, selection in the dredge is dependent on the bar spacing and shell width. Calculating the shell length for a shell width equal to the bar spacing should approximate the size at 50% retention. In this case, the bar spacing for the dredge used in Mace's Bay was 19.05 mm, and the resulting shell length is 39.41 mm.

Beverton and Holt's method is shown in Table 4. This method will break down as L' approaches $L\infty$, but that does not appear to be a problem in this data. Table 4 shows the estimated Z for a range of L' values. Estimated Z's are around 0.02, which is the mortality estimate for much longer lived populations.

The catch curve analysis is shown in Figure 14 and Table 5. This method depends on the selection of fully recruited age and on the estimated age distribution. The major assumption for this method is that recruitment does not vary over the time period represented; this assumption may be violated in this case as not many ages are represented. The resulting mortality estimates of approximately 0.3 seen in Table 5 appear to be too high.

The Chapman-Robson estimates are shown in Table 6 for varying recruitment ages. The estimates of around 0.26 appear high.

The aged sample for this analysis consists of 144 quahogs spread over 21 year classes. This small sample size means that the age-length key used to convert from numbers at length to numbers at age is sparsely populated, making the resulting age distribution questionable. The catch curve method is highly influenced by differences in the age distribution, and the Chapman-Robson estimate depends on the calculation of mean age, which depends on the age distribution. The Beverton Holt and T_{MAX} methods do not use the age distribution directly. The Beverton Holt method depends on the estimate of L_∞ and L'. The estimate of L_∞ may be influenced by the small size of the aged sample, while the estimate of Z ranges from 0.01 to 0.02 over a range of reasonable sizes.

For the determination of the target fishing mortality as $F_{0.33M}$, the estimate based on T_{MAX}, although the simplest, appears to be the most reasonable. With historic fishing mortality in the area near zero, M equals Z which will be assumed to be 0.12. This is much higher than that used for offshore populations of quahogs and that used for St. Mary's Bay across the Bay of Fundy, but it does reflect the size and age distribution from this area.

3.5 – SIZE AND AGE AT SEXUAL MATURITY

Fits to size and age at maturity are shown in figures 15 and 16, respectively. Ocean Quahogs in the study area reach 50% maturity at 38 mm shell length. For the maturity at age, the model did not obtain a good fit to the age data. The method would need younger quahogs in the sample, and these are not retained by the commercial gear used for the survey. The age of 50% maturity is 3.7 from the fit parameters, but this is an extrapolation well outside any of the ages seen in our sample. Table 7 show the size and age statistics for immature, male and female quahogs.

4.0 – ECOSYSTEM AND HABITAT

DFO is committed to an ecosystem approach to fisheries management. The Department also has responsibilities and mandates that include fish habitat, species at risk, biodiversity conservation, and oceans planning and management.

Although there have been studies done on the impacts of clam dredges, most of the work has been done with hydraulic dredges. Little is known about the effects of dry dredges in mud substrates. The fact that mud accumulates in these areas indicates that they are low energy environments, which means the dredge tracks will probably persist for a long time. Examining the by-catch from the survey tows does not give much information on impacts on other species, as the necessity to wash the mud out of the dredges before hauling them on-board means that almost all small and soft bodied organisms are washed out. Table 8 shows the by-catch composition in numbers from the Mace's Bay part of the survey. Numbers are low and the species list small. There were no other commercial species or *Species at Risk Act* species in the survey. Most of the organisms observed were in remaining lumps of clay when the dredge was landed.

5.0 – DISCUSSION

The Mace's Bay area is able to support a small Ocean Quahog fishery. The Grand Manan areas surveyed will produce a sustainable yield at a very low level. Proponents are responsible for the decision if this could be a viable fishery, as this area has additional expenses in transporting the catch to market. This study was not able to survey a large area of interest due to gear conflicts, as the area switches back and forth between two set gear fisheries. Reports of the presence of Ocean Quahogs in this area suggest that if they are not accessible to a fishery they could act as a refuge population and spawning reserve.

The methods used in this study provide a minimum biomass estimate as gear efficiency is assumed to be 100%. In the hydraulic dredges used offshore, dredge efficiency is usually related to the proportion of clams buried deeper than the dredge fishes. Gear saturation may be a more important factor of dredge efficiency when using a dry dredge in clay and mud. If the dredge hits a patch of clay or heavy mud, it may fill up quickly and not fish for the remainder of the tow. Although the depths being fished make diver studies possible, visibility is greatly reduced after a tow and remains so for a period of time while mud settles. Accurate estimates of effective tow length are a large source of uncertainty in the biomass estimate. Gear efficiency and the natural mortality estimate are the biggest uncertainties in determining a sustainable harvest level for this area. Assuming a gear efficiency of 100% should make the biomass estimates conservative. Natural mortality is estimated based on life history characteristics and is, therefore, difficult to estimate with precision.

To ensure long term sustainability of a fishery, management policies must allow animals to have sufficient time to reproduce prior to harvesting. Ocean Quahogs typically mature over a protracted period of time, both as a population and as individuals. The size at age data supports this, with quahogs as young as 13 being mature, while one aged 22 was immature.

The relationship between maturity and size appears to be more precise, and the gear selects on size. A market opportunity for Ocean Quahogs is in the Bay Quahog market when supply is limited by area closures in the U.S. This market is for whole quahogs in smaller sizes, and thus there are concerns about fishing quahogs before they mature. The present commercial gear retains mostly mature quahogs, but if size selectivity changes to small sized quahogs, DFO Management will have to examine methods to manage sizes to prevent recruitment overfishing. A fishery will also be complicated by closures due to PSP, which can occur in the Bay of Fundy during the summer months.

The habitat impacts for a mud substrate are largely unknown at this point. The foot print of a fishery would be small, which may be a mitigating factor, but as this is a low energy environment, the physical disturbance to the bottom will last for a long time.

6.0 – CONCLUSIONS

Given current understanding of the life history of Ocean Quahogs, the populations in this area can support a sustainable harvest. The size and age distribution indicates a higher mortality rate than seen offshore or in the St. Mary’s Bay, Nova Scotia population (Figure 17). The Grand Manan areas surveyed contain 7% of the estimated biomass of the Mace’s Bay area, due to a smaller area and an average density that was only 11% of that of Mace’s Bay. At the estimated biomass of 38,800 t and a natural mortality rate of M=0.12, a harvest level of 0.33M (1,537 t) is considered to be biologically sustainable in Mace’s Bay given the current fishing gear. For the Grand Manan area, the sustainable harvest level would be 107 t.

The selectivity of the commercial gear presently used in the fishery is close to the size at 50% sexual maturity (39.41 mm). It would be beneficial to allow Ocean Quahogs to spawn at least once before they are caught. However, the target F is conservative enough that a large proportion of the quahogs should survive to spawn.

6.1 – ACKNOWLEDGEMENTS

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8.0 – TABLES

Table 1. Biomass estimates for Mace's Bay using kriging and three methods of interpolating the grid produced.

Trapezoidal Rule:	32,355 t
Simpson's Rule:	32,338 t
Simpson's 3/8 Rule:	32,355 t

Table 2. Biomass and harvest estimates (t) for survey areas using statistical and areal expansion methods.

Polygon	Area (km^2)	ACON Biomass	Statistical			ACON	Statistical	Density
			n	Biomass	CI	$B{*}F_{0.33M}$	$B{*}F_{0.33M}$	g/m^2
GM-1	7.4	0.15	10	5.1	±14.6	0.006	0.2	0.7
GM-2	91.5	1,120	80	2,705	±489.8	44.3	58.8	29.6
GM-3	2.9	0.00	1	0	-	0.0	0.0	0.0
GM-7	7.4	403.70	12	992.1	±162.8	16.0	39.3	134.1
GM-8	4.9	31.96	8	217.9	±67.7	1.3	8.6	44.5
Total Grand Manan	114.1	1555.8	111	2,698.9	-	61.6	106.9	23.7
Maces Bay	160.6	32,939	74	38,808.8	±1,437.1	1,264.8	1,536.8	241.6

Note: n = number; CI = confidence interval.

Table 3. Z estimated as $3/T_{MAX}$ with different ages for fully recruited quahogs.

Recruited size	T_{MAX}	Estimated Z
39	25	0.12
40	25	0.12
41	25	0.12
42	25	0.12
43	26	0.115385
44	26	0.115385
45	26	0.115385

Table 4. Mortality estimates from Beverton and Holt (1956) method for selected L' sizes. L' is the minimum fully recruited size.

Size(L')	Estimated Z
35	0.023942
36	0.022636
37	0.021258
38	0.022439
39	0.021080
40	0.019641
41	0.018115
42	0.016494
43	0.014768
44	0.012927
45	0.010959

Table 5. Catch curve analysis for starting ages 18 to 20 for Mace's Bay Ocean Quahogs.

Starting Age	Estimated Z
18	0.338957
19	0.325925
20	0.307635

Table 6. Chapman Robson estimates of Z with different fully recruited ages.

Starting Age	Estimated Z
18	0.267543
19	0.263671
20	0.259292
21	0.285525
22	0.296980

Table 7. Statistics on the size (in cm) and age (in years) at maturity for Ocean Quahogs from the 2006 Mace's Bay Ocean Quahog survey.

A - Size at Maturity:

	Immature	Mature Male	Mature Female
Average	38.36	44.43	46.53
Std. Dev.	4.57	4.77	6.23
Minimum	29.00	36.00	41.00
Maximum	44.00	58.00	62.00
n	11	35	15

B - Age at Maturity

	Immature	Mature Male	Mature Female
Average	18.55	18.65	18.64
Std. Dev.	2.38	1.61	1.28
Minimum	13.00	15.00	17.00
Maximum	2.00	21.00	20.00
n	11	34	14

Table 8. By-catch from the SWNB Ocean Quahog survey in numbers.

Species Name	**Common Name**	**Number**
Arctica islandica	Ocean Quahog	11,526
Astarte sp	Astarte clam	146
Molpadia oolitica	Purple sea cucumber	98
Cyclocardia borealis	Northern Cyclocardia	74
Pitar morrhuanus	False Quahog	46
Placopecten magellanicus	Atlantic Sea Scallop	36
Neptunea lyrata decemcostata	Wrinkle Whelk	10
Arabella iricolor	Red segmented worm	6
Colus sp.	Whelk - Colus Sp.	4
Cerianthidae	Tube dwelling anemone	3
Ctenodiscus crispatus	Mud Star	3
Chone infundibuliformis	Smooth tube worm	2
Homarus americanus	Lobster	2
Mytilus sp.	Mussel	2
Actiniaria sp.	Sea anemone	1
Cancer borealis	Jonah Crab	1
Cancer irroratus	Rock Crab	1
Cryptacanthodes maculatus	Wrymouth	1
Cucumaria frondosa	Orange-footed sea cucumber	1
Gastropoda	Snail - Unidentified	1
Laminaria saccharina	Kelp	1
Myxicola sp.	Fan tube worm	1
Pandalus borealis	Northern Shrimp	1
Polychaeta	Polychaete - Unidentified	1
Spionidae	Spionid Worm	1
Total		11,969

9.0 – FIGURES

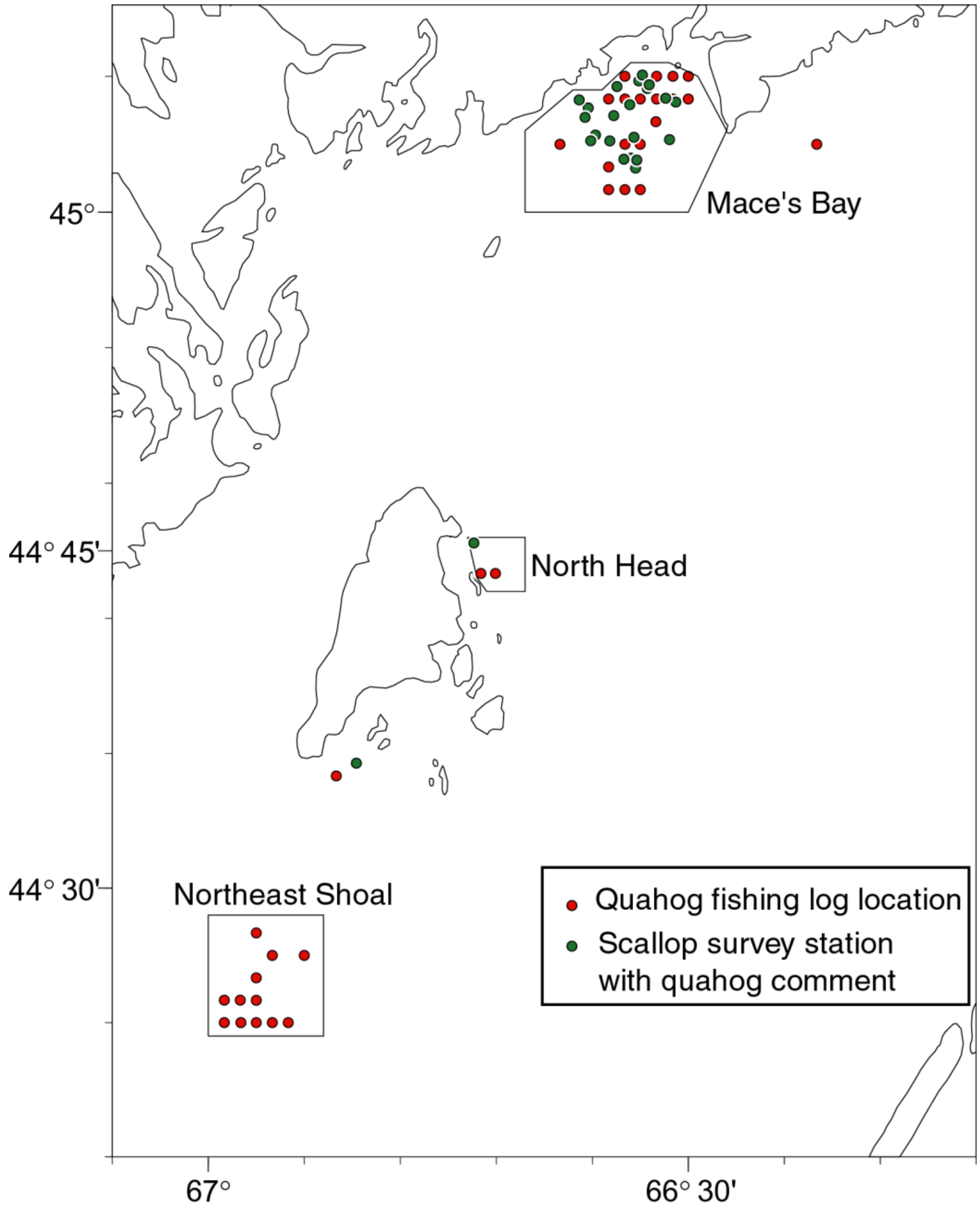

Figure 1. Quahog fishing locations from 1998-2003 logbooks, and scallop survey tows with comments on quahogs or quahog shells in the catch for 1998-2003 scallop surveys.

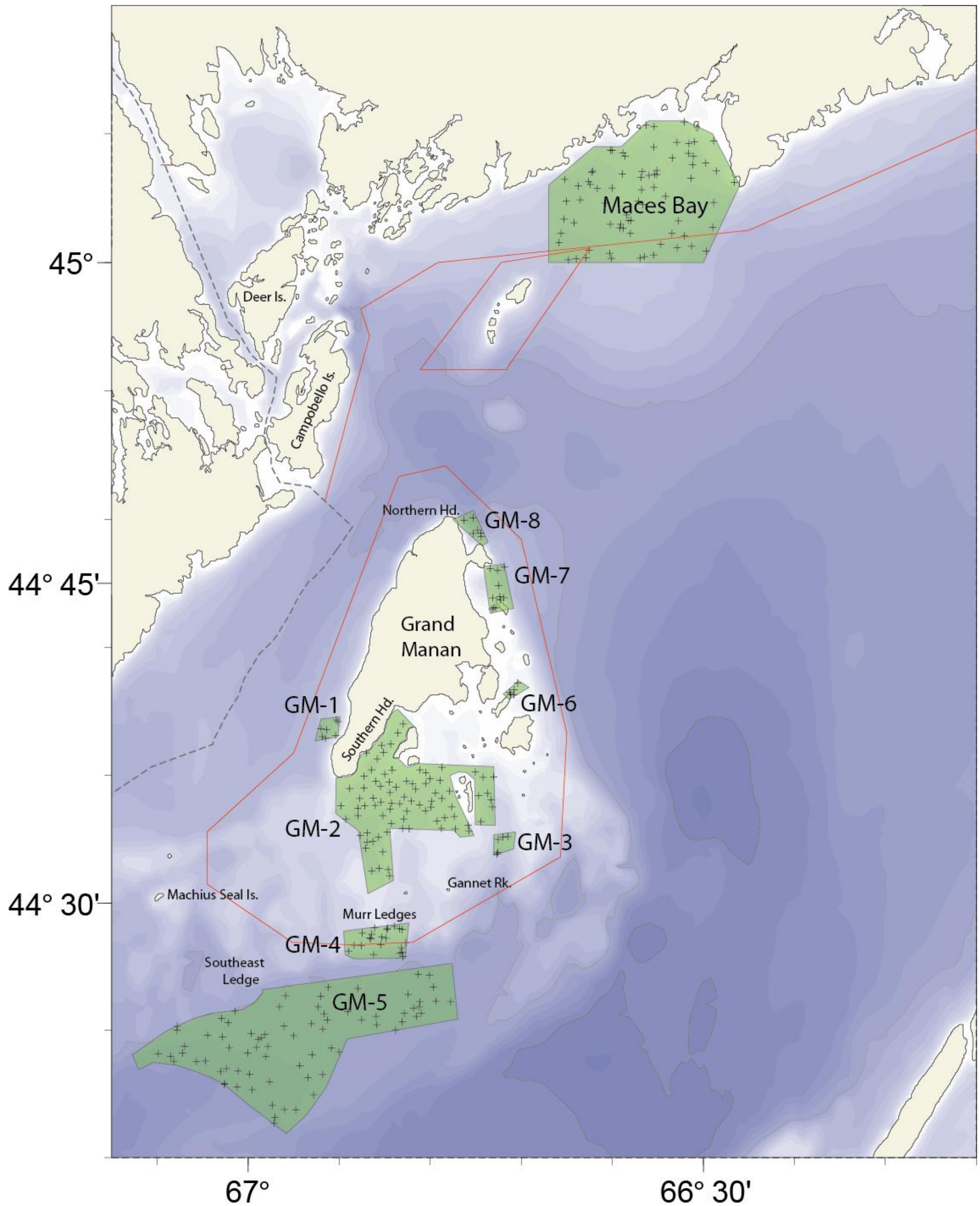

Figure 2. Survey areas and station allocations for SWNB Ocean Quahog survey.

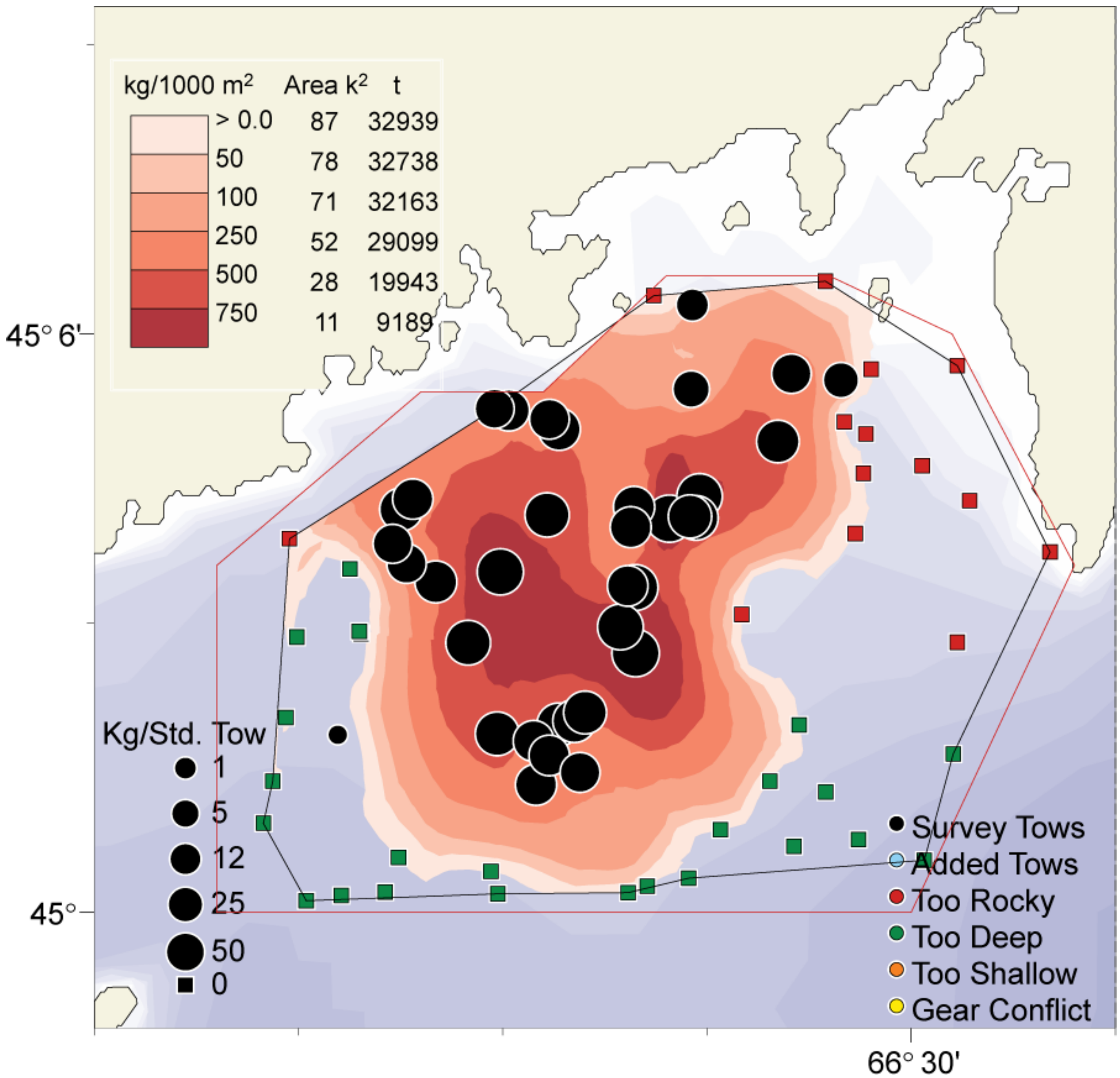

Figure 3. Survey results for Mace's Bay area.

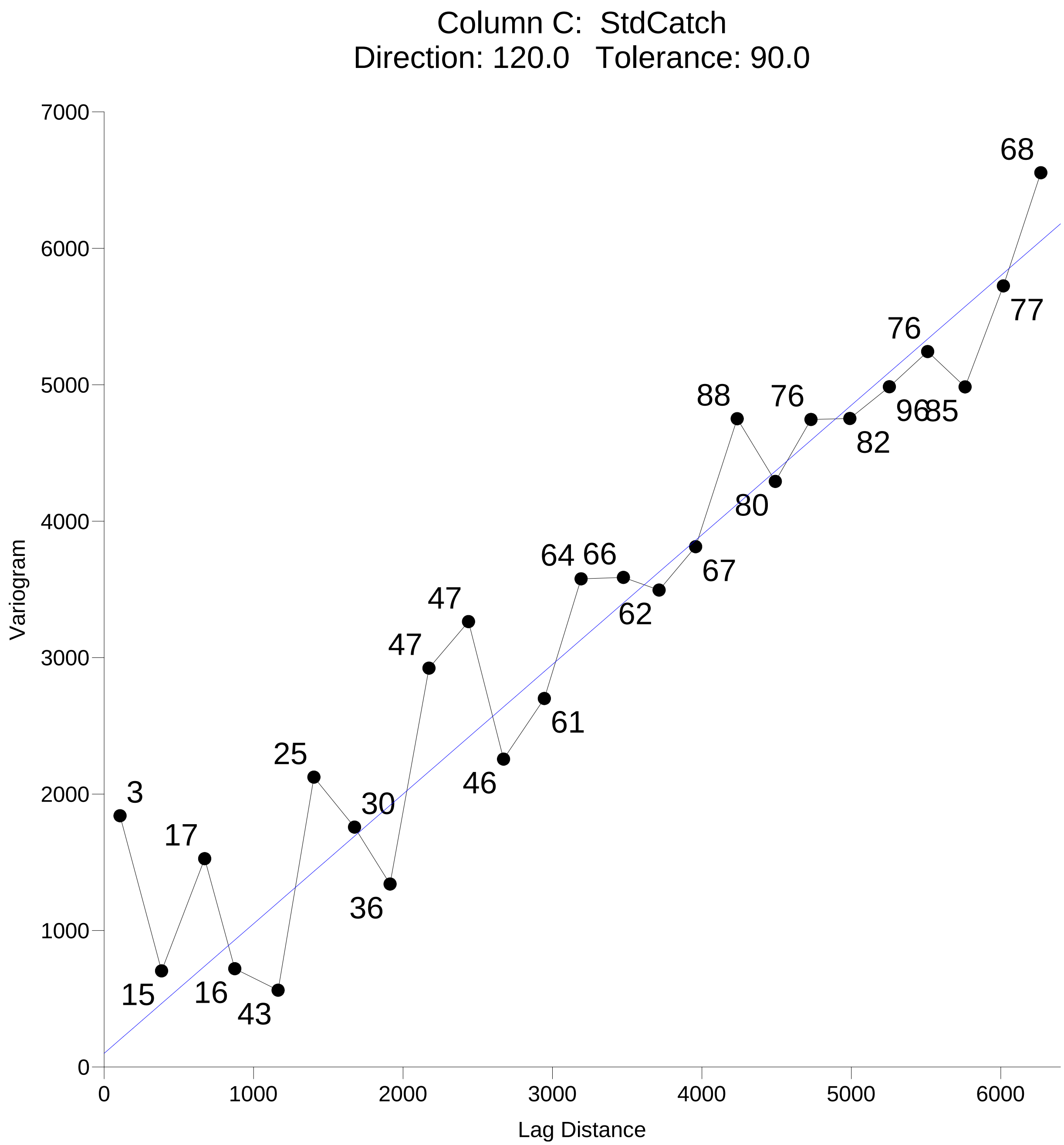

Figure 4. Variogram for Mace's Bay Ocean Quahog Survey results.

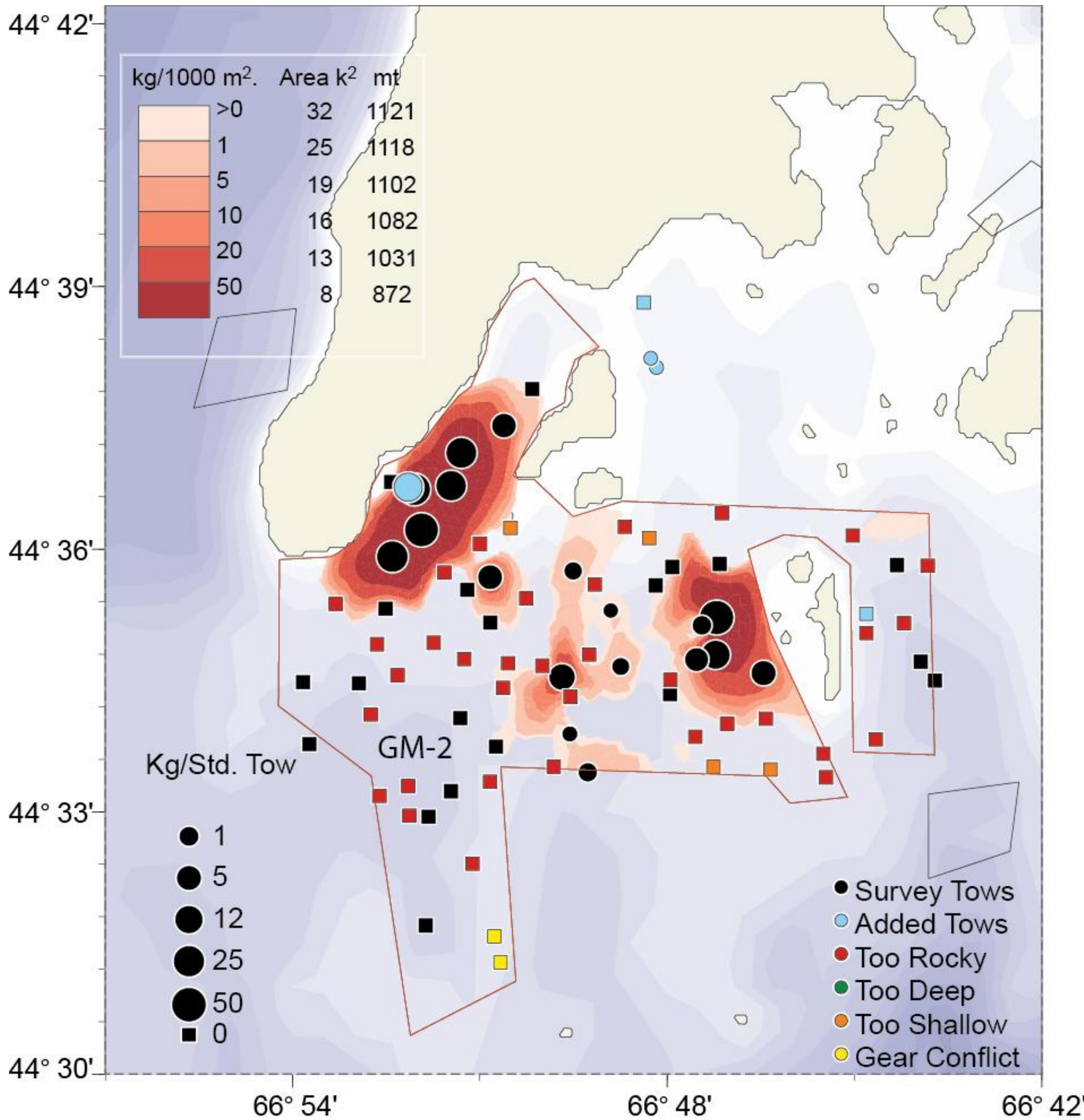

Figure 5. Station locations and ACON contouring and biomass estimates for area GM-2 from the 2007 Grand Manan Ocean Quahog survey.

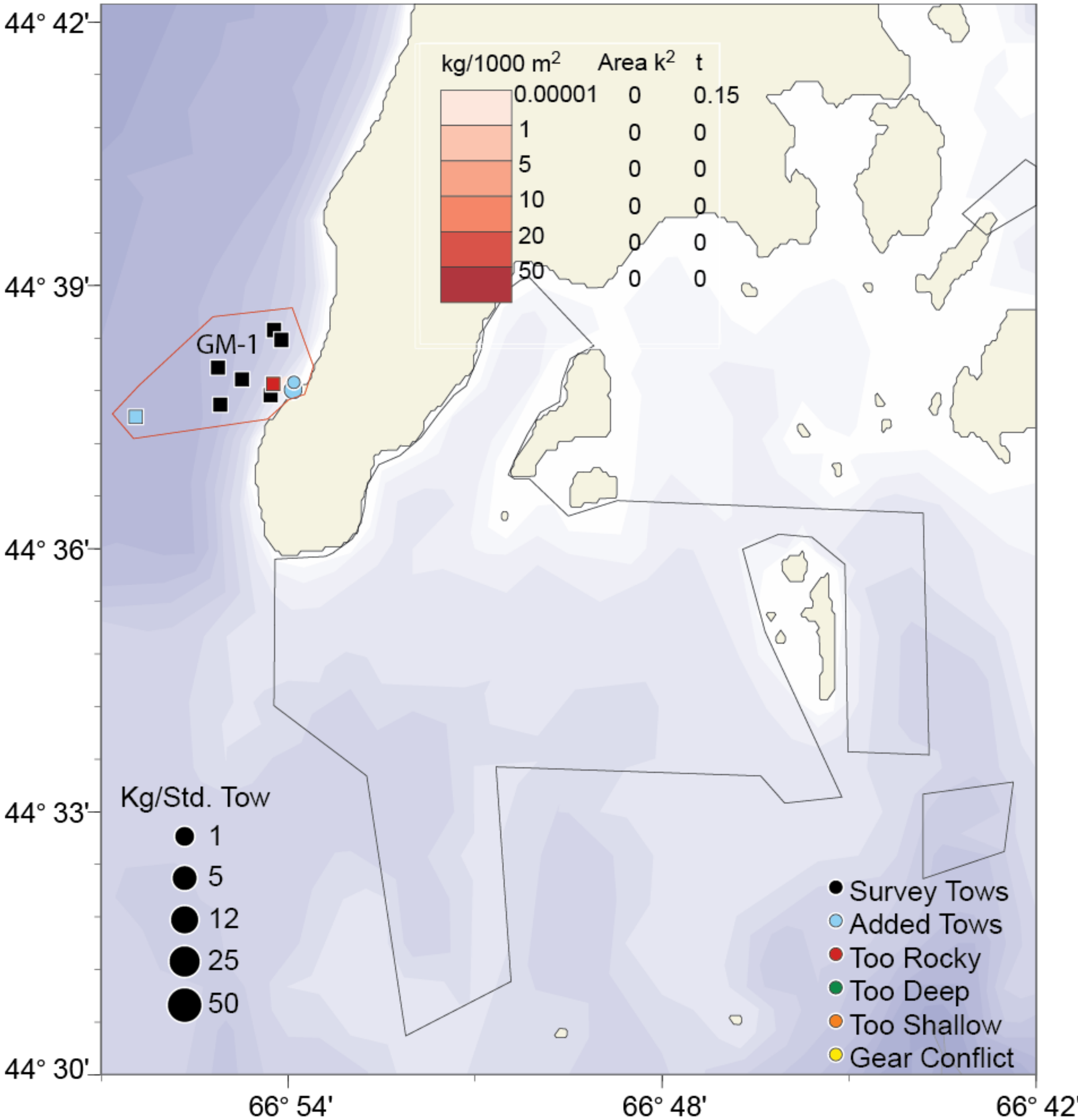

Figure 6. Station locations and ACON contouring and biomass estimates for area GM-1 from the 2007 Grand Manan Ocean Quahog survey.

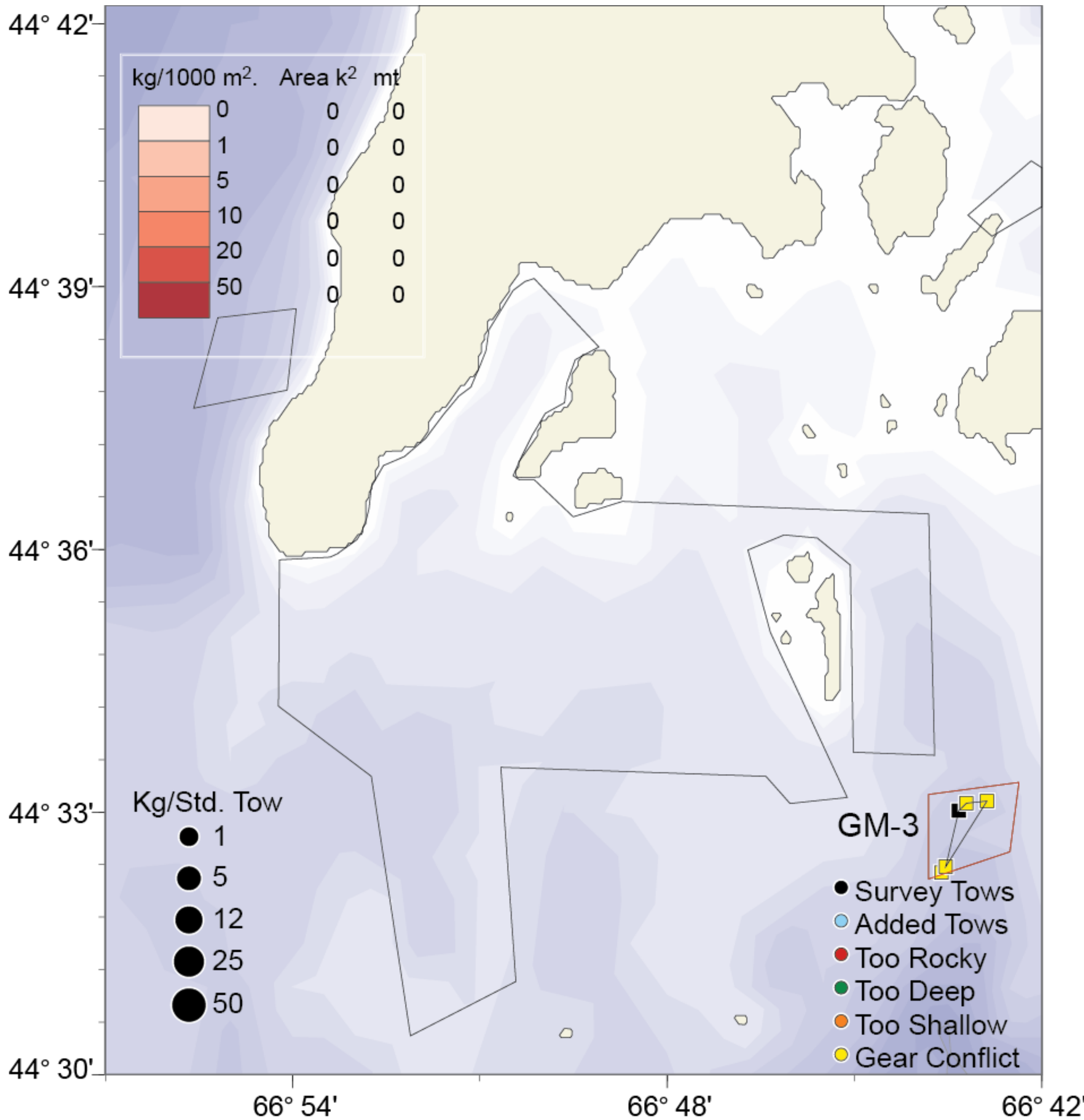

Figure 7. Station locations and ACON contouring and biomass estimates for area GM-3 from the 2007 Grand Manan Ocean Quahog survey.

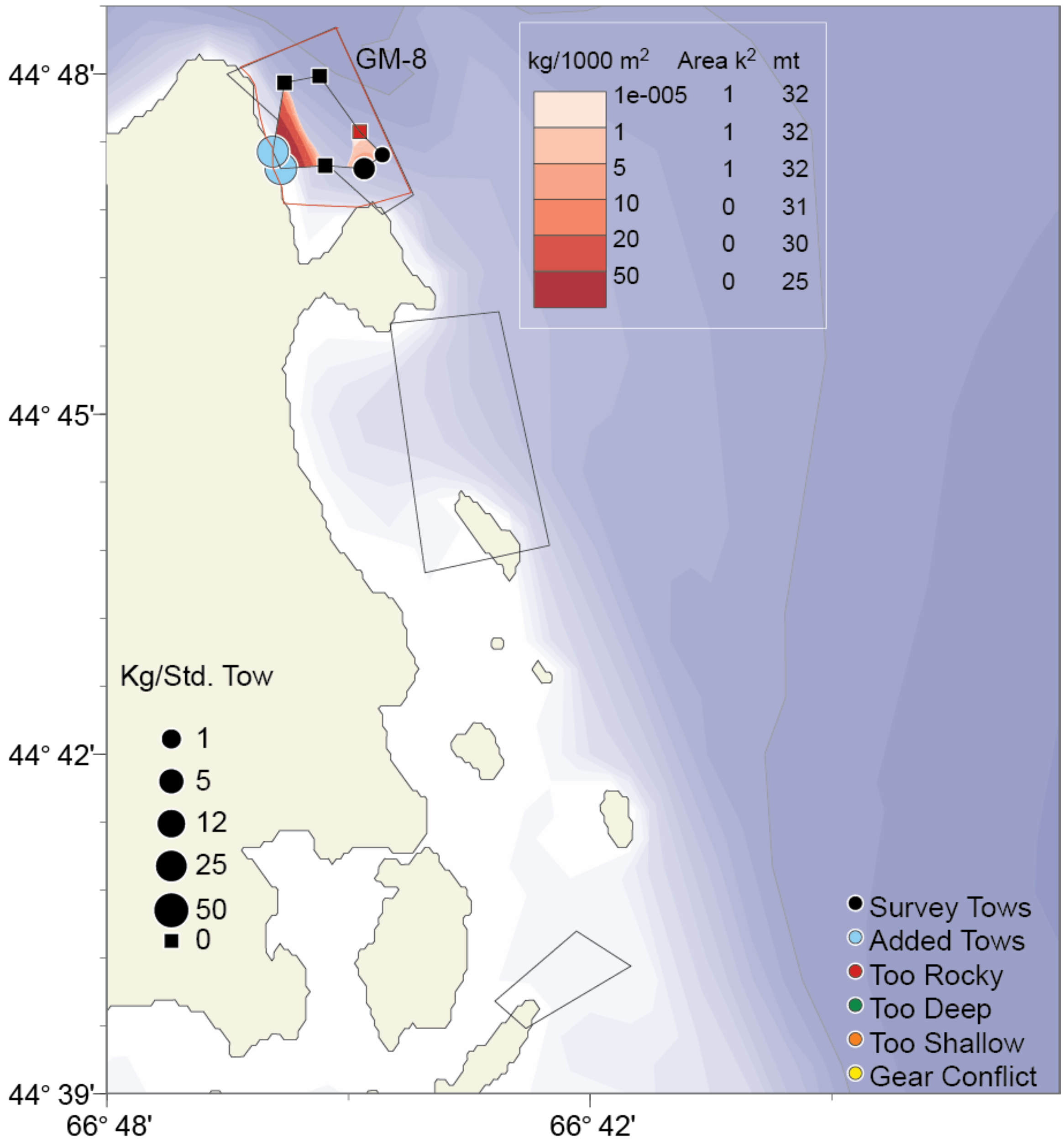

Figure 8. Station locations and ACON contouring and biomass estimates for area GM-8 from the 2007 Grand Manan Ocean Quahog survey.

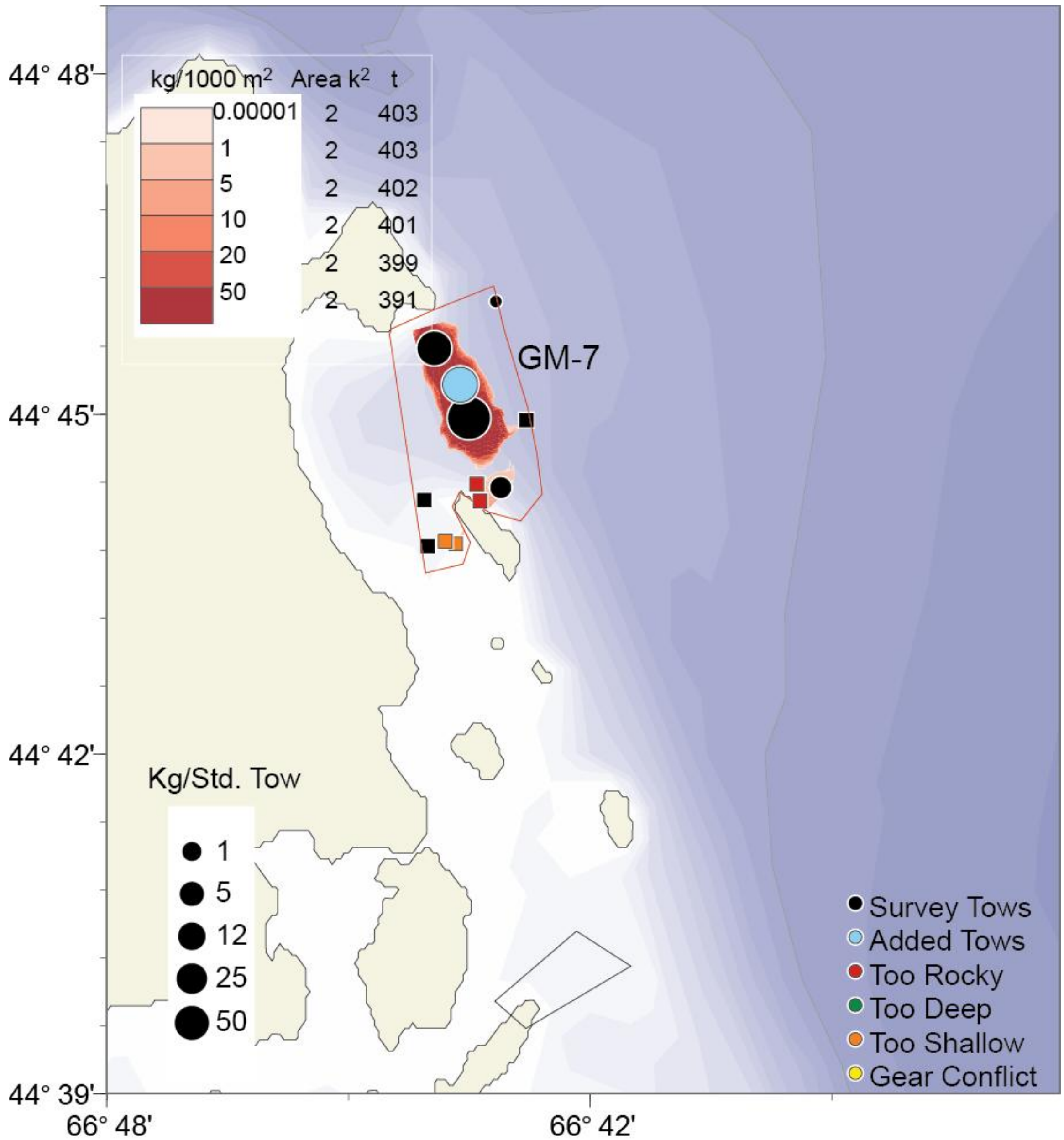

Figure 9. Station locations and ACON contouring and biomass estimates for area GM-7 from the 2007 Grand Manan Ocean Quahog survey.

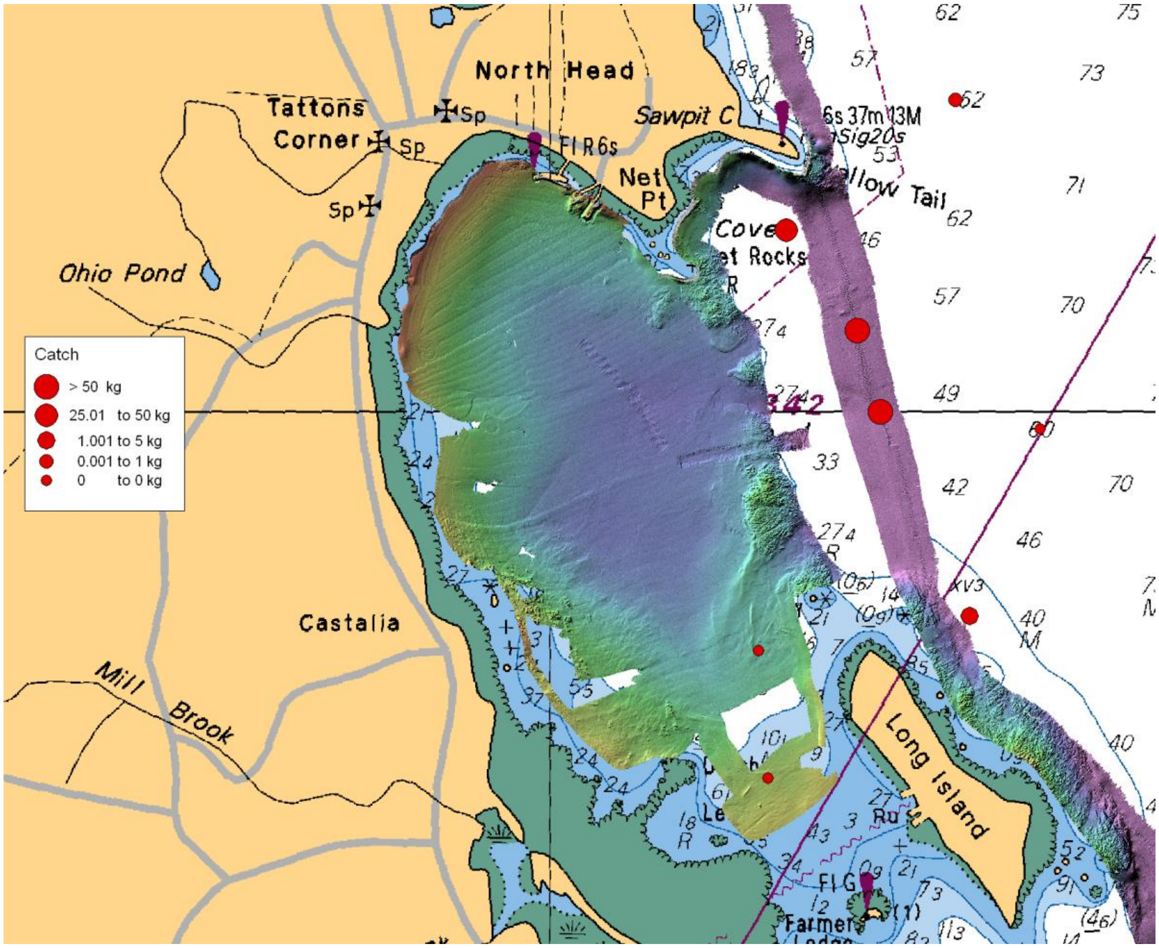

Figure 10. Station locations overlaid on bathymetry for the GM-7 survey area from the 2007 Grand Manan Ocean Quahog survey.

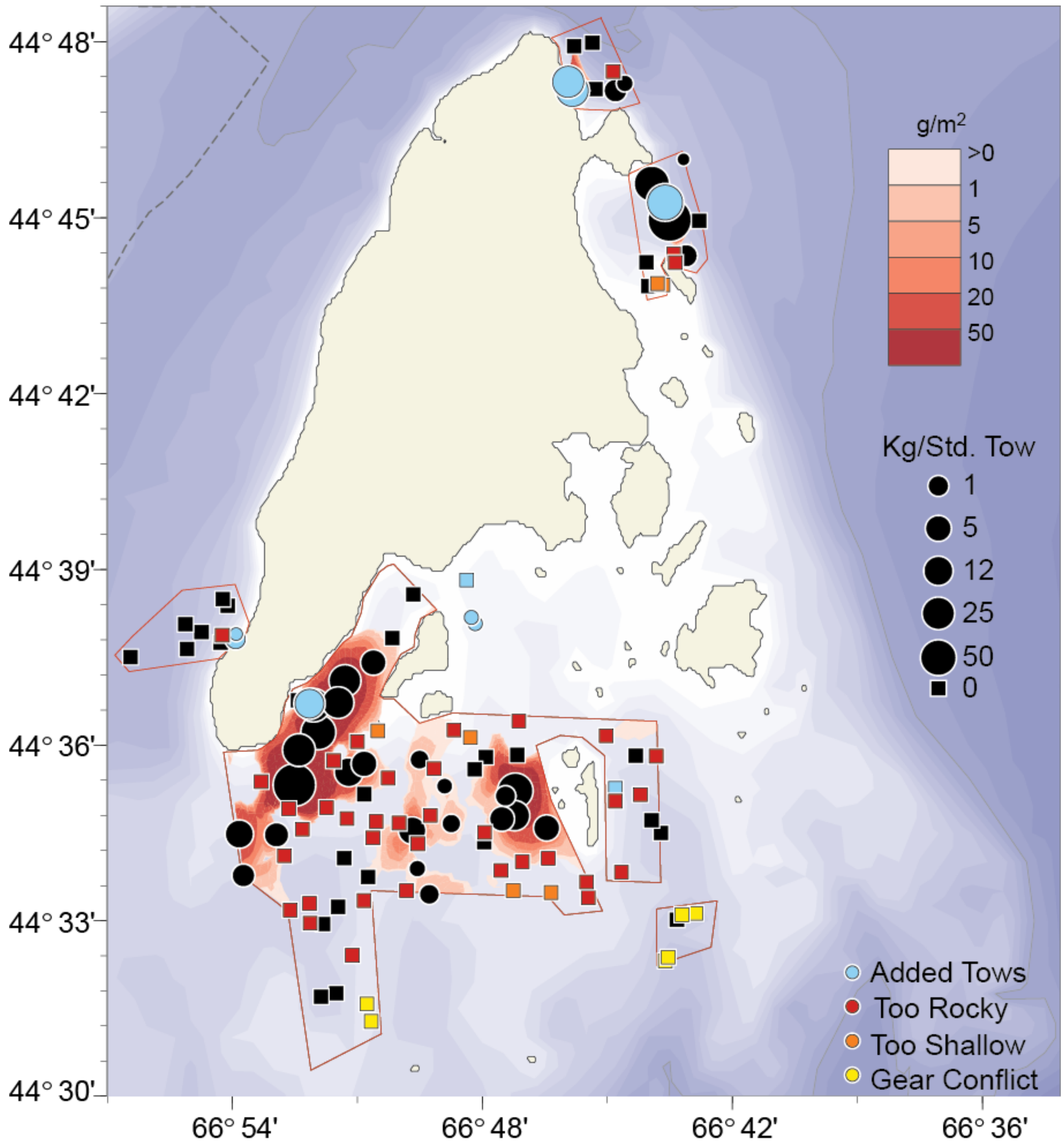

Figure 11. Station locations and ACON contouring for all areas from the 2007 Grand Manan Ocean Quahog survey.

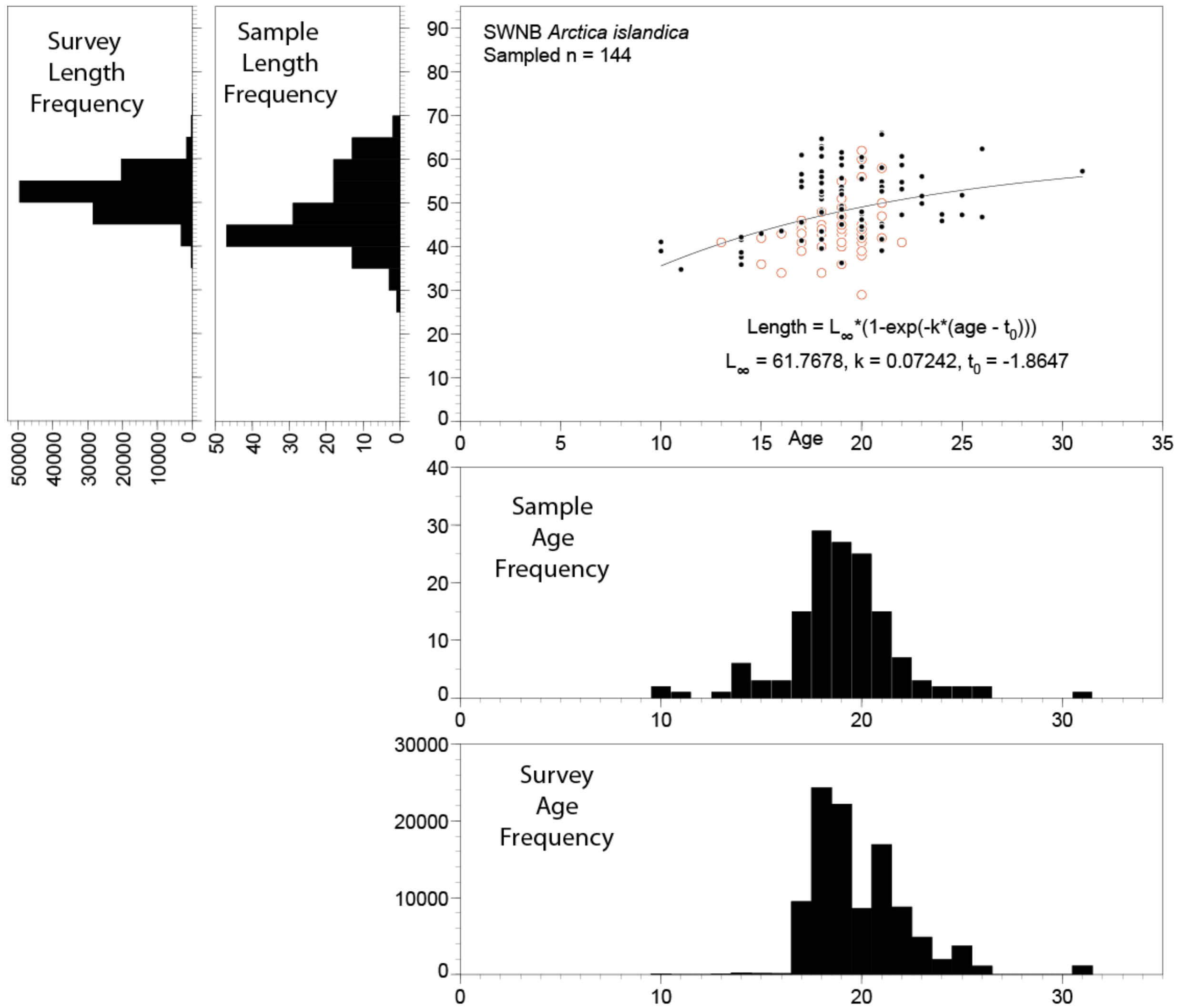

Figure 12. Ageing results for ageing of Ocean Quahogs from the 2006 Mace's Bay Ocean Quahog survey. Circle symbols indicate quahogs used in the maturity study.

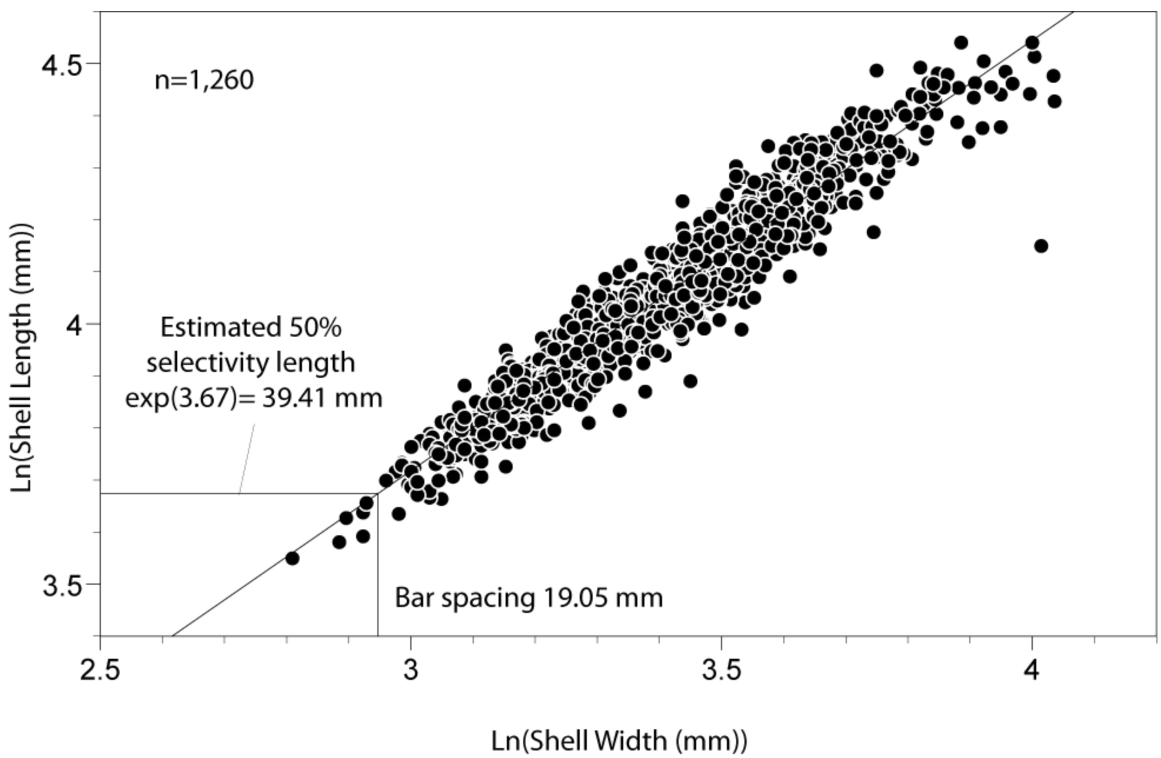

Figure 13. Linear regression of log of shell length on logged shell width. Regression parameters allow for the estimation of the size of 50% selectivity based on the bar spacing of the dredge.

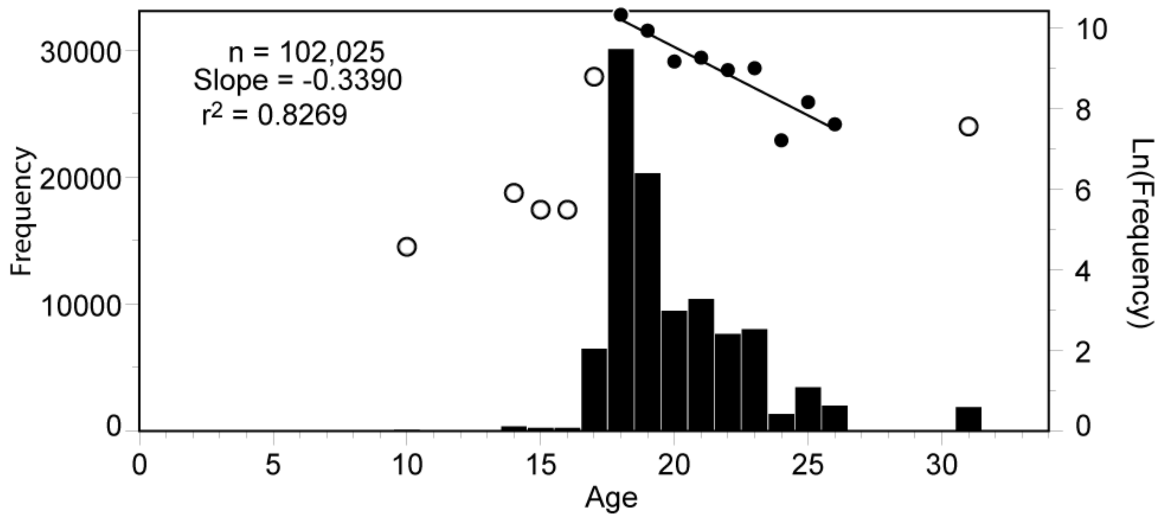

Figure 14. Survey age frequency distribution estimated with length frequency data and length – age matrix from aged sample. Logged frequencies are shown as circles, regression line is catch curve for ages marked as filled circles.

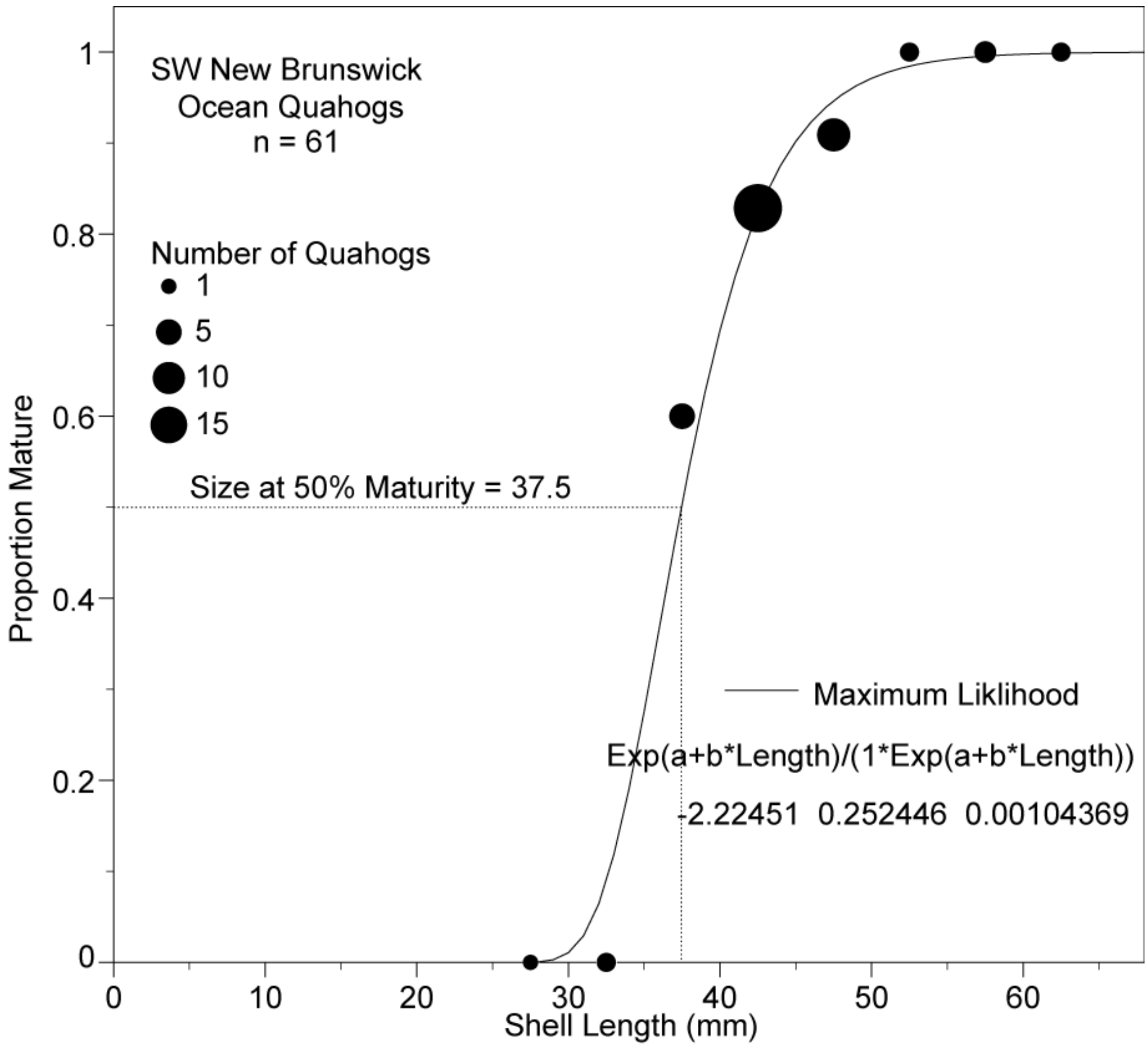

Figure 15. Richard's curve fit to the size at maturity data from the 2006 Mace's Bay Ocean Quahog survey.

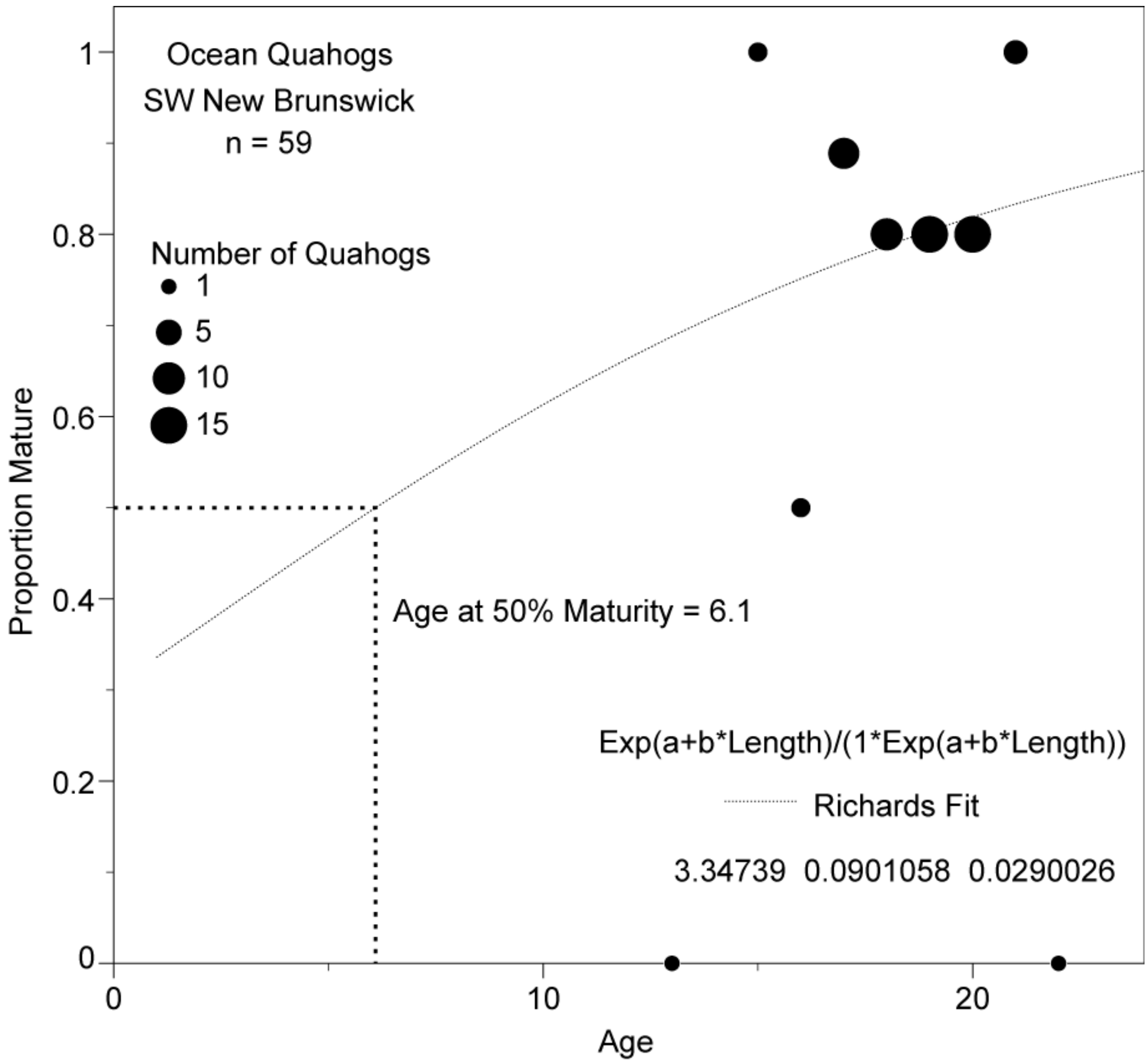

Figure 16. Richard's curve fit to the age at maturity data from the 2006 Mace's Bay Ocean Quahog survey.

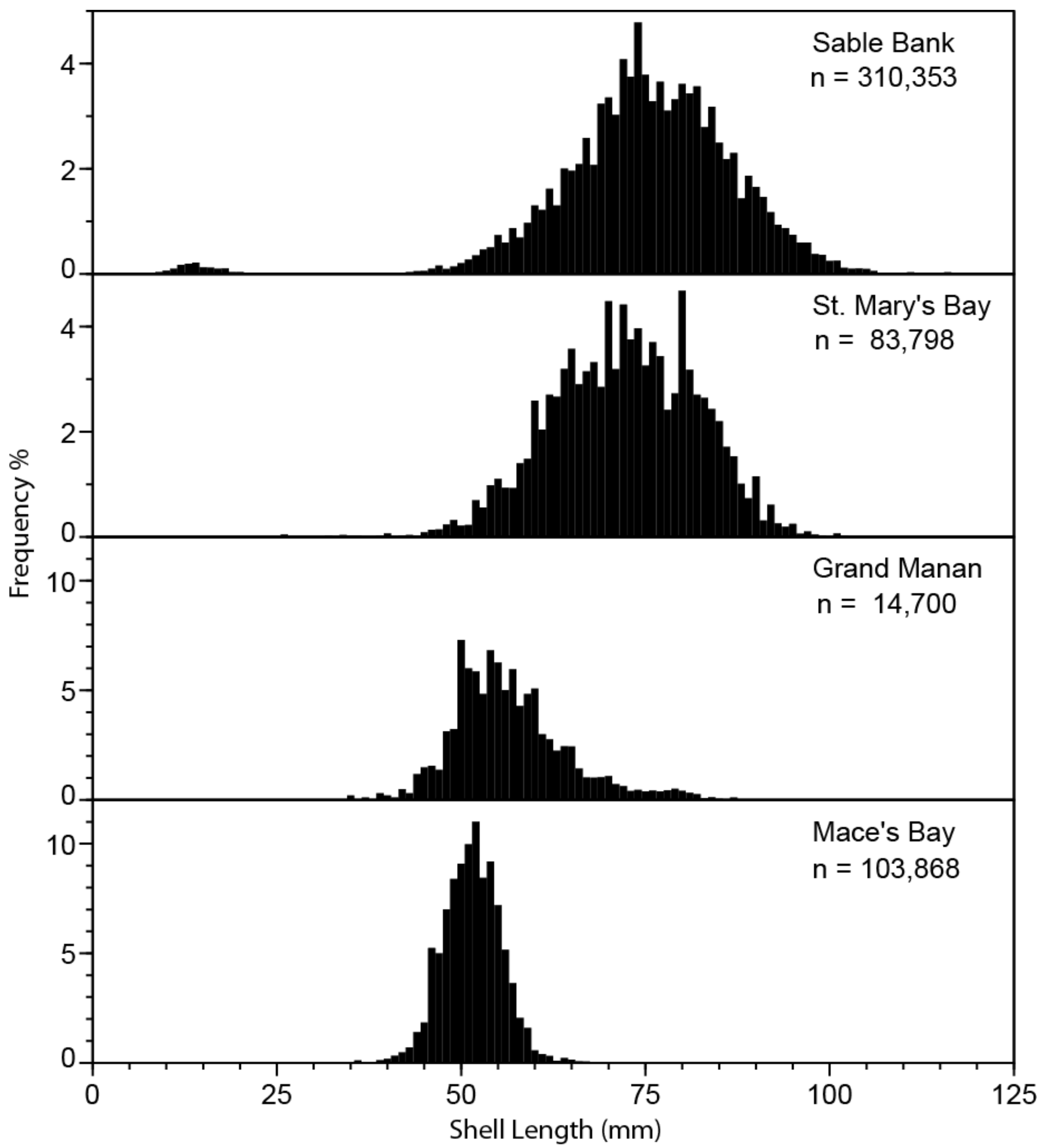

Figure 17. Comparison of length frequencies of Ocean Quahogs from different populations in the Maritimes.